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ABSTRACT

Recent research on human factors in the man-machine communications interface is reviewed and discussed as it relates to the problem of establishing optimal system response times for the various kinds of tasks performed at the computer terminal. Optimal system response time is operationally defined, and the conflicting demands of system design, system performance, and computer users are outlined. A description of the task environment is provided, along with an analysis of the cognitive and behavioral characteristics of "general" and "naive" users, and a number of other considerations related to system response time are addressed. Response time measurement and specification are described as an integral part of the system design process, user-relevant measurements of response time are defined, and a rating scale for system response-time requirement specification is presented. An 82-item bibliography, a cited-author index, two figures, two tables, and appendices on various measures of system response and on the purpose and scope of user interface studies accompany the text. (JL)

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Technical Report

on

OPTIMAL RESPONSE TIMES IN AN ONLINE INTERACTIVE COMPUTING ENVIRONMENT: CONSIDERATIONS AND GUIDELINES FOR SYSTEM DESIGN

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ABSTRACT

A review of the human factors literature and recent research on the man-machine communications interface in interactive computing systems reveals a growing consensus regarding certain key elements to be designed into an effective and satisfying user-system interface. Among these user-oriented elements are optimal system response times for various kinds of tasks to be performed at a computer terminal. The notion of establishing an absolute standard for minimal system response time is rejected. Instead, several factors, such as the nature of the task, and the cognitive and behavioral characteristics of the user, must be reviewed carefully prior to establishing response time requirements for specific transactions in particular interactive computing applications. In this report "optimal system response time" is defined as "that set or mix of time-dependent factors in interactive problem solving and task execution which maximizes the effectiveness of overall, ongoing performance in the specific task-performance environment, without bringing about a corresponding decrease in the level of user satisfaction with the system."

Psychological requirements to be considered in the design of the user-computer interface include those associated with a human's short term memory span and the need for closure in the task execution cycle. The former is important in establishing maximum system response times for effective interaction, and the latter is relevant in determining the appropriate tempo of interaction at various stages of the task performance cycle. The variability of system response times for the same kinds of tasks is viewed by the user as more problematic than longer response times that are, nonetheless, uniform throughout a task performance session.

The analysis of user requirements prior to the design of an interactive system must include the system response time requirements for a specific class of users in a specific task performance environment. These requirements must then be included in the functional specifications as design objectives. A system response time specification scale is presented for this purpose. This proposal varies from the traditional approach which omits time considerations from the analysis of user needs and requirements, but rather attempts, after system development, to "fine tune" the system to provide "as fast as possible" system response time.

CONTENTS

ABSTRACT iii

1. A DOZEN YEARS AT THE USER-COMPUTER INTERFACE: CHANGING DESIGN PRIORITIES AND THE EXPANSION OF RESEARCH EFFORTS 1

1.1 Defining the Challenges and Opportunities for Human Factors Research 1
1.2 New Computer Users and Conflicting Design Goals 2
1.3 The Developing "Community of Consenus" Regarding Human Factors Guidelines 3

2. RESPONSE TIME AND PERFORMANCE: CONFLICTING POINTS OF VIEW AND SYSTEM DESIGN GOALS 5

2.1 Conflicting Design Goals and Objectives 5
2.2 Two Points of View on System Performance 5

3. OPTIMAL RESPONSE TIMES AND THE TASK-PERFORMANCE ENVIRONMENT 8

3.1 The Components of an Interactive System 8
3.2 Optimal System Response Time Defined 8
3.3 The Task-Performance Environment 9
3.4 Cognitive and Behavioral Characteristics of "General" and "Naive" Users 10

4. RESPONSE TIME AND PSYCHOLOGICAL CONSIDERATIONS 12

4.1 Reductive Analysis and the Complex Mix of System Temporal Parameters 12
4.2 An Explanation of the Divergent Definitions of Response Time 14
4.3 System Response Time and Related Measures Defined 15
4.4 User Response Time and System Response Time Dependencies: Method Chunks and Rhythms of Interaction 15
4.5 Two Fundamental Principles for Considerations of the User Interface in Interactive Systems 18
4.6 Psychological Factors and Response Time Requirements 18
4.7 The Effects of Variability in Expected Response Times 21
4.8 Appropriate Statistical Measures for System Response Time 21
4.9 Criteria for Determining the Optimal Mix of Response Time Summarized 22

5. RESPONSE TIME MEASUREMENT AND SPECIFICATION IN THE SYSTEM DESIGN PROCESS 23

5.1 User-Relevant Measurements of System Response Time 23
5.2 A Rating Scale for System Response Time Requirements Specifications 23
5.3 The Place of Response Time Specification in the Design Process 24

6. APPENDIXES 27

A. Various Measures of System Response 27
B. Guide to the Scope and Purposes of User Interface Studies 28

7. BIBLIOGRAPHY 29

8. CITED AUTHOR INDEX 40

LIST OF FIGURES AND TABLES

Table 1. Time-Based Measures 13

Figure 1. "Interarrival Time" 17

Figure 2. "User Response Time" 17

Table 2. Design Process for Interactive Systems 25

The evaluation of systems in terms of human usability requires not only an extensive range of knowledge and expertise, but the ability to see the forest through many kinds of deceptive foliage, of differentiating the operationally valuable from the theoretically valuable. It requires the knowledge that when measurement is used as a basis for evaluation, a generalization is being based on sampling operations. But finally, if measurement of the human factor is to be genuinely useful, a substantial amount of creativity needs to be brought to bear both in what to look for and how to observe (measure?) it--not in terms of writing a technical paper for a learned society, but for improving both the system's design and the lot of the humans who will be dependent on its usability.

[Human Ease of Use Criteria and Their Tradeoffs, Robert B. Miller, IBM Poughkeepsie Lab, (48)]

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1. A DOZEN YEARS AT THE USER-COMPUTER INTERFACE: CHANGING DESIGN PRIORITIES AND THE EXPANSION OF RESEARCH EFFORTS

"As the world turns" in information science, computer systems, and data processing applications, a decade may witness two or three generations of birth and development. With each generation an abundance of problems and challenges present themselves to systems designers who must creatively exploit a dazzling array of new technologies, while at the same time being "constrained" by the user's needs and requirements. In no area of applied computer and information science have the challenges been greater than in online, interactive systems where a direct end user interfaces with the system via a terminal, and employs an operational language designed uniquely for that purpose. The "human factors" challenge, as it has become known, encompasses a vast array of communications needs and requirements arising from the "user interface in interactive computer systems." (The latter descriptive terminology attained common acceptance in the early 70's, as illustrated by the titles of the human factors review articles in the 1972 and 1973 volumes of the Annual Review of Information Science and Technology.)

1.1 Defining the Challenges and Opportunities for Human Factors Research

A dozen or so years ago, for many information scientists and system designers, "man-computer communications" began its steady and determined rise toward the top of the priority ladder. While the human factors challenge was being clarified and help was being sought from the behavioral sciences, the lack of progress in applying experimental methods to factors at the user interface, and the apparent absence of a user requirements orientation, were the subject of widespread lament throughout the emerging literature. In an early effort to identify the major problems and issues, Nickerson, et al. (52), at the 11th Annual Meeting of the Human Factors Society in 1967, state their thesis: "...the emergence of computer time-sharing and the resulting developments pose an extraordinary challenge to human factors specialists and point up one of the most promising areas for human factors research during the next decade--and beyond." Beginning with the assumption that human factors have become important for both economic and psychological reasons, the authors then proceed to note a few of the major considerations, including:

conversational pace
short term memory and job swapping
system response time
ease of use, and
the effect of charging algorithms on system use.

In the December, 1969 issue of IEEE Transactions on Man-Machine Systems (51), Nickerson refines both his presentation of the urgent issues and the problem of reluctance by researchers to address these issues. Against the backdrop of a rapidly increasing heterogeneous community of users, users who are not computer specialists and who view the computer only as a tool to facilitate their work in other fields, Nickerson's renewed exhortation is mixed with cynicism: "The challenge that this development offers to psychologists and human factors researchers is obvious; unfortunately, it is not so obvious that

this challenge has been accepted." And a page later, based on a brief review of the literature, he continues,

> In short, there is remarkably little evidence of research that has been undertaken for the express purpose either of increasing our understanding of man-computer interaction or of providing information that will be useful in the development of systems that are optimally suited to user's needs and preferences. I have been able to find only about a dozen articles in these sources on the topic of interest.

The three problem areas Nickerson discusses are the development of conversational languages (including time-dependent factors), the relations between use patterns and system characteristics, and the descriptive modelling of man-computer interaction. Curiously, the paper that immediately precedes Nickerson's in the volume is titled "Man-Computer Interaction--The Contribution of the Human Sciences." It is not a lengthy paper.

Presenting an even more disparaging summary of the state of human factors research in the April, 1970 issue of Human Factors (65), H. Sackman, of the System Development Corporation, opens somewhat passionately: "A sustained tradition of applied experimental work in man-computer communication does not exist... As things stand now, the user is the forgotten man, and the general public stands to suffer in the long run from this pervasive experimental and humanistic lag in information services." Sackman then goes on to make a plea for interdisciplinary cross-fertilization between behavioral and computer sciences as the means to bridge this humanistic gap.

1.2 New Computer Users and Conflicting Design Goals

Today, a dozen years since these observations and admonitions, the picture is a good deal brighter. The challenges have been accepted and creatively fragmented into many diverse areas of expertise and experimentation along the human-computer interface continuum. The analytic, experimental orientation now prevails among an informal, international community of researchers and system designers representing government agencies or "think tanks," R and D units in business and industry, universities, and information networks and utilities. Validation of interface hypotheses is no longer an uncommon announcement in the research and design literature.

Ramsey and Atwood (61), in their 1978-79 review of the human factors literature pertinent to computer systems, started with several thousand articles of some relevance, then selected several hundred for their detailed analysis of the variety of interface studies. The authors concluded, however, that more, better-targeted, experimental research was still needed, and that while sufficient knowledge had been gained to develop a qualitative human factors design manual, there was not yet sufficient evidence for a quantitative standards manual. In a similar review of performance models applicable to man-machine system evaluation, Pew, et al (59) focus on the unfilled promise of an integrated model of human performance capable of rigorously representing command and control system performance at the user interface in an interactive system.

Some of the abundant research on the human-computer interface, especially in the area of combined user-system performance, remains preliminary in nature. The results of this research await further confirmation from repeated and refined experimentation ranging from computer monitoring, to user interviews, protocol analysis, and unobtrusive measurement of user activities. But now it is time to recognize and capitalize on the progress of the last dozen years; progress revealed not only in accumulated knowledge and insight, but also through the vastly increased sensibility toward the overriding importance of the user interface in the design and production of interactive systems.

The challenges, some new, some old, have changed since the late sixties. They are no longer the subject of lament. Instead, as Ben Shneiderman has summarized in his recent book, Software Psychology,

> Providing useful tools for computer users with a wide range of experience, problems, skills, and expectations is a challenge to scientific competence, engineering ingenuity, and artistic elegance. System developers are increasingly aware that ad hoc design processes, based on intuition and limited experience, may have been adequate for early programming languages and applications but are insufficient for interactive systems which will be used by millions of diverse people.(67)

The challenge is best characterized today by the existence of conflicting design goals, concludes Shneiderman.

Systems should be powerful, flexible, responsive, easy to use, efficient, with costs kept low. "Finding a smooth path through these conflicting goals is a challenge." Urging a continued, disciplined experimental path as a condition for progress, Shneiderman cites the achievements and fundamental insights, transcending specific systems, by researchers like Nickerson (51), Bennett (6), Martin (42) R.B. Miller (48,49), and L.A. Miller and Thomas (46), as well as many others. He likens the approach of these experimentalists to the careful, painstaking methods of the mosaicists. Each experiment is like a tile in a mosaic. As the tiles are pieced together, a picture begins to emerge of the factors that are important in system design from a human performance point of view.

1.3 The Developing "Community of Consensus" Regarding Human Factors Guidelines

Although not derived from the application of the rigorous protocols and standards of the experimental scientist, another source of evidence has emerged which may be viewed as equally important and relevant. A "community of consensus," an international aggregate of researchers and designers, has grown from the last decade of combined effort and the free exchange of the results of that effort. An informal consensual validation has occurred. A disinterested, loosely related (by professional society membership and journals) group of individuals and teams with various organizational affiliations have expressed agreement regarding the issues, remaining problem areas, and the guidelines and some standards that may be applied to user acceptance and performance factors at the user-computer communications interface.

Until recently, this phenomenon of emerging shared insight and agreement has not been appreciated or reviewed in detail. The appended bibliography is a nonexhaustive selection of the evidence of this growing consensus at many points, as represented in the published literature. The keyword used to determine the initial selections along with those repeated above (man-machine systems, user interface, user-computer performance, etc.) was "response time."

As Lorraine Normore states in her recent review of the human factors literature prepared for Chemical Abstracts Service and The Ohio State University Research Foundation (53), "Only when a number of different studies provide substantial agreement about the utility of a certain system feature can the reader be relatively confident of drawing a valid conclusion." It is on this consensual basis that the conclusions regarding the time dependent aspects of the user interface and user-computer performance have been reached. Illustrations from specific studies will be offered to support these conclusions and other related considerations. Of course, these conclusions may be viewed as tentative, and in the Popperian sense, all scientific conclusions are tentative, that is, subject to disconfirmation by yet to be discovered evidence. Regardless, as designers, we must continue to apply shared insights with an orientation toward the user's performance and satisfaction with a new utilitarian artifact that is ever increasingly invading his work environment.

2. RESPONSE TIME AND PERFORMANCE: CONFLICTING POINTS OF VIEW AND SYSTEM DESIGN GOALS

2.1 Conflicting Design Goals and Objectives

Of the many elements contributing to a given mix of user-task-performance characteristics at the human-computer interface, no parameter of performance has been the subject of more explanation and defense, yet has remained so confused and enshrouded in the clouds of apparently irreconcilable conflicts of expectancies and goals, as response time. In the overall environment of online, interactive computing systems, the designer is often presented with several conflicting design goals and points of view:

(1) The fastest response time is best, or, at least, "the faster--the better."
(2) Response time should match the complexity of the command or system work required.
(3) System performance should not vary over time.
(4) Too fast can be too demanding, creating tension or fear in the user.
(5) Too slow will lead to impatience and frustration, alienating the user or causing a lowering of productivity.
(6) Variance of response time should be eliminated even at the cost of increasing the mean response times of certain command-transaction cycles.

The resolution of these seemingly irreconcilable points of view or conflicting sets of design goals emerges from the objective consideration of two different but related realities: (1) There are two fundamentally different points of view regarding the capabilities and performance of a computer system, that of the conventional computer system operations manager and DP professional, and that of the direct end user of the system; (2) A growing body of solid insights and evidence now exists, offering guidance regarding the psychological and task-performance constraints and requirements which can be brought to bear on these vital design decisions.

2.2 Two Points of View on System Performance

In the frequently cited "Guidelines for Man/Display Interfaces" developed for IBM interactive computing environments by Engel and Granda (22), the authors trace the confusion and conflicts over response time to the

> Failure to discriminate between the capabilities and operating characteristics of the user on the one hand and those of the computing system on the other. The operating characteristics of the system are definable in terms of specific actions executed by the hardware and/or programming configurations. Quantitative estimates are relatively easy to obtain.

Researcher David Stevens pursues this failure and its contributing sources from another direction (73). "What is the entity whose performance is to be managed?", he asks. The conventional EDP response points to three

organizational levels at which performance evaluation and management can be meaningful:

> (1) the organizational units (departments) directly responsible, (2) the entire "system, and (3) the hardware.

According to Stevens most of the performance management efforts are extended at one end of this environment, and are aimed at the other,

> In the sense that hardware-oriented measurements are used as the primary line of defense against criticism directed toward the department as a whole: the traditional response to complaints about quality of service is a litany of impressive-sounding statistics about 'availability,' CPU utilization,' 'overlap,' etc.

Not ignorant of the value of such measurements for pinpointing bottlenecks and related system problems, Stevens reminds us that these statistical rationalizations fail to explain aspects of system behavior of interest to the users, and more often "obfuscate" the issues.

When users complain about poor service such as slow or irregular response times, they are holistic in their orientation to the system. They do not want to know about the relative performance levels of the various components of the system architecture. Their curiosity about the system's facilities does not extend to an interest in learning about the complex and variable relationships between hardware/software interactions and perceived system performance. In fact, users often have a more complete and realistic understanding of the constituents of the "system" than do EDP professionals. The system includes the user-confronted hardware (terminals) and software applications (command language, error messages, display formats), other people, institutions and networks, a given physical environment, and policies and procedures. The users interact daily with all of these elements, in direct and dependent relationships, and not with the system hardware and software control programs. A measurement and reporting policy which does not include the user-confronted elements of the system, as perceived by the user, is incomplete and of little value in responding to user's complaints. These limited measurement policies seem unsympathetic to a user's pleas for some explanation.

It is an element of fundamental wisdom to avoid crossing purposes of performance measurement and reporting. Traditional system performance measures have an appropriate domain of application, for example, as diagnostic tools, and as the ultimate source of much vital management information needed at the highest levels of governance and policy formation. According to Stevens, these performance measures, and the reports based on them, do not address the issue of actual system performance directly, as viewed by the user, "and performance <u>is</u> what it seems to the users to be."

The relevant factors and considerations for service and performance at the user interface from the user's perspective will be reviewed below, but first it is necessary to understand that there are two fundamentally different points of view on system performance measurement and evaluation, each valid within its own operational framework and decision support or decision-inducing

realm. In his computer system measurement and performance textbook, MIT's Svobodova insists that we maintain this distinction:

> Performance of a system can be discussed from two different positions: first, the effectiveness with which the system handles a specific application; and second, the internal efficiency of the system. Effectiveness is what is seen by the system user. Efficiency is how the system uses its resources in order to process the respective workload.... Effectiveness measures are the prime performance measures. Values of these measures can be assessed from observations made at the external side of the evaluation interface: they are what is seen by the system users.(75)

There are potential dangers, however, in embracing or exploiting these points of view at cross purposes, dangers for the perceived credibility of technical communications and for the continued spirit of cooperation in identifying areas of problems and improvement in the level of services provided to users.

3. OPTIMAL RESPONSE TIMES AND THE TASK-PERFORMANCE ENVIRONMENT

3.1 The Components of an Interactive System

"The design and evaluation of interactive computer systems should take into account the total performance of the combined user-computer system. Such an account would reflect the psychological characteristics of users and their interaction with the task and the computer," (11, my emphasis) state Card, et al in their recent report of the use of a keystroke-level model for user performance. This task-performance orientation is consistent with the analysis of the user interface summarized by IBM's Bennett, (6). "By observing what goes on at the interface between the user and the terminal, we can identify the impact that design decisions have on user performance." Bennett presents a four-part outline of the components of an interactive system:

(1) the task to be performed,
(2) the user,
(3) the terminal, and
(4) the computer-stored information content.

Reminding us of the intrinsic interdependence of these components which constitute the entire interactive system, Bennett concludes, however, that the task, in a sense, governs all the others. "Task characteristics determine the behavior required of the user at the terminal, suggest the nature of the data that will flow between the user and the computer store, and indicate the logical structure of information to be shown on the terminal." The challenge for the designer is to synthesize this mix of components to provide a user interface that will support the interactive problem-solver and task-performer. No one should be surprised, chides Bennett, by the affirmation that the user is a component in the interactive system. "Since the goal of interaction is to improve the user's task performance, it is clear that we must understand his needs, his skills, and his motivation as he uses the terminal."

3.2 Optimal System Response Time Defined

Optimal system response time, from the user's point of view, is that set or mix of time-dependent factors in interactive problem solving and task execution which maximizes the effectiveness of overall, ongoing performance in the specific task-performance environment in which he operates. It may be desirable to add to this definition, "without bringing about a corresponding decrease in the level of user satisfaction with the system." The relationships between user satisfaction and effective performance at specific tasks are not yet well known or confirmed by observation, but they do appear to be separate measures of service at the user interface. The elements of user satisfaction and techniques for measuring and assessing these elements are currently being defined and tested (19,28,56,76), but the final priority, more performance, or more user satisfaction, will be determined at the specific task-performance environment level by the user.

With the possible exception of the leisure time, hobby environment, the above definition assumes that the terminal and all the resources of the computer

system exist primarily as sophisticated tools aiding users to perform their tasks more efficiently and effectively than was previously possible. In a production/performance environment, features which increase user satisfaction (e.g., reliability, ease of use, responsiveness, help commands, clear and constructive error messages) should be provided. But, no increase in styling or user-cordial features will assure continued user acceptance if the system does not contribute to the maximization of performance in a given task environment.

3.3 The Task-Performance Environment

The "task-performance environment" is the work environment where people make a living, whether in providing a service or manufacturing a product (and all the support processes required for either), in which standards of quantity and quality exist, are known, and are applied to the well-defined activities of the employees involved in providing that service or product. In his landmark study of human ease of use criteria, R.B. Miller calls this the "procedural environment"(48). "The procedural environment determines what the user-operator can do, should do, and does do. Procedure design is equivalent to task design and should be guided by psychological knowledge about human behavior and performance." In this environment, requirements usually exist for throughput and quality, and individual performance is evaluated on the basis of these standards. From the employees' practical point of view, when these standards are known (and even sometimes internalized) as the organization's expectations of them, their motivation can be explained by their awareness that their performance levels will be a deciding factor in considerations of increased compensation and career advancement. It is within this sort of task environment that terminal operators and occasional users of the system's interactive facilities will have high expectations for computer services, and that the day-to-day terminal operator will understandably voice strong demands for improved performance features such as access, reliability, and response time.

The task and the user cannot be considered separately, of course. The user's psychological characteristics, needs, and requirements within a specific task-performance environment must be studiously approached by the designer attempting to synthesize the most effective interactive interface. Avoiding generalities and abstractions for the moment, these are users working part or all of their working day at the terminal, carrying out such tasks as:

- -searching for a bibliographic record;
- -entering data for a book order transaction or cataloging routine;
- -editing or updating, line by line, existing records of order, cataloging, or circulation information;
- -posting receipt of serial publications or other materials;
- -updating fund records.

The glamour of the computer as the exclusive tool of a small, self-appointed elite in the world of libraries and library applications is rapidly vanishing. At this time of diversified production and marketing of information services and library products, it is especially important to keep our sights on the actual end users of the system's equipment and services. It is these users' cognitive levels of capability and needs within specific task-performance

environments that also are undergoing change and diversification. A one-dimensional, romantic vision of the typical system user will no longer do.

Today, the tasks to be performed at the interface are numerous. These tasks are becoming more and more routinely clerical and can be performed by terminal operators whose training does not need to include professional library or information science education. Bibliographic searching and verification at the interface now takes its respected place among many required tasks undertaken at the terminal in library operations, and it now constitutes a diminishing proportion of these activities. With the development and provision of online public access catalogs which can be used directly and effectively by the user without the help of a trained intermediary, even the bibliographic searching and retrieval tasks will have to be tailored for another kind of user in yet another kind of task-performance environment.

3.4 Cognitive and Behavioral Characteristics of "General" and "Naive" Users

The increasing number of users for whom effective interactive interfaces must be provided do share some common cognitive and behavioral characteristics. The majority of their routine tasks also require many similar capabilities and terminal dependent activities across diverse computer applications. Miller and Thomas have attempted to identify the behavioral issues related to the use of interactive computers primarily by persons who are not computer professionals, but who they designate as the "general user"(46). The general user interacts with computer systems to achieve specific task goals of any nature, and the authors believe "that the key to achieving substantial improvement in the computing environment lies in a better understanding of a general user's task characteristics and goals."

Miller and Thomas propose a dual-level classification of human tasks pertinent to the interactive interface: (1) The class of routine tasks, characterized by specific procedures-directed activity, short in duration, producing information-conserving or information-reducing transformations on the input data and (2) the class of problem-solving activities, of which there are many types, each having its own requirements and objectives. The authors strongly believe, however, that sufficient evidence exists regarding the behavioral issues pertinent to user-interface activity, that when collected, can provide a general reference that applies to all cases. In their attempt at a comprehensive taxonomy of features characterizing interactive systems, they also propose alternative implementations, based on the best evidence provided by behavioral studies and "emphasizing the functional capability that should be provided in the interactive environment." The first system performance characteristics they review are system response time, availability, and reliability.

Another characterization of the new computer user, solidly grounded in observation, has been offered by K.D. Eason and associates of the University of Technology, Loughborough, Leicestershire (20). Their research, conducted over several years, centers on the so-called naive computer user.

Selecting users from a wide variety of backgrounds, their aim is to develop guidelines for designers who have the responsibility of identifying the important characteristics of the potential users of their systems. Their

definition of the naive computer user, and the attributes common to such users, are worthy of consideration primarily because of the broad empirical basis of the research undertaken. "We define the naive computer user as a person who is not an expert in computer technology but who uses a computer system to assist him in the performance of a task." Assuming this definition in their surveys of various systems and hundreds of users, Eason discovered four attributes common to naive computer users.

(1) They need the computer for the performance of specific tasks and will evaluate its performance according to its ability to serve these tasks. If the system serves the user's needs poorly, the system as a whole stands condemned.
(2) The interests and aspirations of most naive users lie in the work they do and not in the tools they are obliged to use. They do not have a deep knowledge of, or interest in, computer technology in general, or of the particular system in use.
(3) They seek to minimize the time and effort required to use the computer system. It is merely a means to an end, and any unnecessary activity which has to be devoted to the means is an obstruction to the accomplishment of performance requirements and objectives.
(4) Given all of the above, the naive users are "at risk" in the use of computer systems. Faced with a system malfunction, erratic response, or unexplained error response, the user may experience frustration or even trauma leading to an extended period of cynicism and non-acceptance of the computer as a helpful tool.

This research group recognizes that some of the above attributes are more critical for some users than others. They propose a three-level model for guiding the systematic observation and analysis of behavioral situations for the purpose of discovering the pertinent characteristics that are common to, as well as those that differentiate, certain types of computer users. In addition to information processing task factors, job/role factors and personal factors are vital subjects for investigation. A person's job-related role expectations and self-image (different, for example, for a data entry operator or a manager) play a large part in shaping his/her behavior with a computer terminal and determining what sort of terminal behavior will be acceptable. The consideration of personal factors must include the variables of age, intelligence, and values, as well as attitudes and personalities. Deeper analysis often reveals, however, that user problems and apparent user limitations or inadequacies are contributable to task or job/role related factors. After describing their work in these areas, as observed in various work environments, the authors reach this conclusion: "task factors tend to define the sophistication of the service the user requires whilst the job/role factors define the effort he will be able and willing to provide to use the system." [sic]

4. RESPONSE TIMES AND PSYCHOLOGICAL CONSIDERATIONS

4.1 Reductive Analysis and the Complex Mix of System Temporal Parameters

The intrinsic dynamical characteristics of an interactive, time-sharing computer system provide numerous time-dependent factors which pose multiple challenges to the system designer, operations and performance manager, and researchers in their separate but related efforts to improve system efficiency and effectiveness. In the whole complex mix of these temporal parameters and measures making up a given system, there is much multi-level and multi-directional interdependence among the performance-determining elements. Some of these interdependencies are more easily identified and measured than others (see Table 1).

The manner in which this mix of temporal parameters is divided, or sliced into ever-smaller fragments can usually be explained by the objectives of the reductive analysis and measurement techniques as applied to a particular system. The deeper the reduction into smaller and more numerous time fragments, the more necessary it is to employ mathematical formulae and models to complete the analysis and to acquire meaningful data. This combined level of reduction and abstraction is necessitated by the overwhelming complexity and staggering quantitative characteristics of large, powerful, interactive computer systems. Such sophisticated measurement and analysis are often required in the ongoing task of detecting system bottlenecks or "drag" points, and in fine-tuning the system within the constraints of the existing hardware-software configuration.

From the internal, system-defined perspective, excellent analyses and methodologies have been presented which, although applicable to the identification, measurement, and fine-tuning of system parameters, take their point of departure from what Abrams and Treu have called, "the consumer-oriented viewpoint toward 'service' directed measurement."(3) IBM's Silverman and Yue offer a methodology for the statistical evaluation of computer performance in information retrieval systems which operate in a teleprocessing environment under a multiprogramming operating system. "The performance criterion chosen is response time, because it is the quantity of prime importance in a query system."(68) The authors identify the job requirement parameters and system environment parameters and use the derived model to trace the lifetime of a dismantled message through the system during response time. This is an exhaustive attempt to identify the determining variables within the system and all their possible interrelationships which may impact on delayed response time.

A companion article is presented by Chang in the IBM Journal of Research and Development (13). One purpose of this analysis of terminal response time in data communications systems is to facilitate the initial phase of system design.

> One of the key factors in design and evaluation of such (teleprocessing) systems is the calculation of terminal response time....Systems differ widely in their response time requirements, and the response time needed can, in turn, have a

major effect on the design of the data transmission network and the data processing facilities.

Chang identifies all the response time elements, from polling wait to output transmission, but the key point is that specific response time requirements for various user input transactions (e.g., simple inquiry, data entry, inquiry and update, and complex inquiry) can and should be established along with other functional requirements prior to system design.

TABLE 1. Time-Based Measures
(Abrams and Treu,3)

NUMBER/NAME	VARIABLE/FORMULA Single	Cumulative	UNIT OF MEASURE	MEANS OF MEASUREMENT	COMMENTS
Time-Based					
1. System Delay	t_{1i}	$\sum_{i}^{n} t_{1i}$	sec	1,2	Where $1 \leq i \leq n$, for n system responses per session
2. System Transmit	t_{2i}	$\sum_{i}^{n} t_{2i}$	"	"	Also called printout or output display time
3. Acknowledgement Delay	t_{3i}	$\sum_{i}^{n} t_{3i}$	"	"	Time from input carriage return to first system reaction
4. Acknowledgement Transmit	t_{4i}	$\sum_{i}^{n} t_{4i}$	"	"	Reflects length of that reaction (which may be entire system response)
5. User Delay	t_{5i}	$\sum_{i}^{n} t_{5i}$	"	"	Includes user read, think, etc. time
6. User Transmit	t_{6i}	$\sum_{i}^{n} t_{6i}$	"	"	Includes time required for user input typing
7. User Task	t_{7j}	$\sum_{i}^{n} (t_{1i}+\ldots+t_{6i})$ (restricted i)	"	"	Where $1 \leq n_1 < j \leq n_2 \leq n$, and the jth task is delimited by transactions nj through n_2
8. Selected Subsession	t_{8k}	$\sum$ (restricted i)	"	"	Where i is restricted to those contiguous or non-contiguous transactions defining the kth special subset
9. Interprocess Transfer	t_{9p}	$\sum$ (restricted i)	"	"	Where i is restricted to those transactions involving movement between different software or hardware processors
10. Session Start, Finish	t_{10}, t_{11}		"	1,5	
11. Total Session	$t_{11}-t_{10}$	$\sum_{i}^{n} (t_{1i}+t_{2i}+\ldots+t_{6i})$	"	1,2,5	Which may consist of one or more successive user tasks, as well as use of one or more processors

MEASUREMENT OR IDENTIFICATION MEANS:
1. Application of Network Measurement Machine
2. Software analysis of collected data
3. Software search and identification within alphanumeric data base
4. Human search and identification within alphanumeric data base
5. Access to available accounting records

4.2 An Explanation of the Divergent Definitions of Response Time

Response time, as a major temporal parameter in all discussions of computer system performance and service to the user, has acquired many faces and roles. These different appearances can be accounted for both by the context of the discussion and by the particular mix of its constituent elements presented for description and analysis. The definitions of response time usually offered near the outset of any discussion, are, ironically, very similar, if not identical in their "macro-level" characterization of this important performance criteria. This is, perhaps, the real source of the confusion and conflict over what response time is and how it should be measured. The preliminary, common definitions of response time focus directly at the locus of the user interface with the system: the terminal, and its observable behavior. All agree, that in some sense, response time as an elapsed period begins and ends at the terminal, between action A, and event B. Most agree that action A is the last action of the operator for the input of information requiring a response, and that action B is an observable system signal which constitutes at least a part of the required response (see Appendix A). However, as the discussions continue, and different component elements of response time are revealed for analysis and measurement, the original concept, still defined in common at the macro level (as ordinarily observable by a user at a terminal) frequently undergoes a transformation and becomes completely meaningless to the typical user. Yet it is from the results of these "system-side" analyses and measurements that gross statistical measures of merit (such as "average response time for March") are chosen to represent the relative performance of the entire system for a given period of time.

On the other side of the terminal, however, sits the operator, minute by minute, day by day, experiencing either good or poor response time in a very different way. Within this task and role-determined environment of the user, systemwide aggregate measures of response time have little meaning. Even when supervisors and administrators learn that one or two seconds have been shaved off the system's monthly average response time, this is seldom communicated to the actual terminal operators. It appears that vital, high-level management information pertaining to the performance of the system is being used both for marketing purposes and for conveying glad tidings of improved response time to the users. There is no meaningful way, however, that the terminal user can translate a single, aggregate statistical quantity (the average of all response times for the month) into perceived patterns of improved or degraded response time during interactive cycles at the terminal.

The interface (the user performing tasks at a terminal) has become a communications barrier of a sort. Once the generally common definition of response time is applied to that locus, additional analysis, measurement, and reporting usually proceed away from the user. Therefore, from a human factors and user service orientation, it is necessary to take the concept, its development in operational terms, further analysis, and new measurement techniques directly over to the user's side of the terminal.

4.3 System Response Time and Related Measures Defined

For this discussion, system response time is the period from the last keystroke made by the user in the input operation (this involves depressing the message-terminating key, such as the SEND key or the return key) to the instant the first character of the system response is displayed or typed at the user's terminal. With terminals employing a keyboard lock feature, it has been suggested that the system response time period by definition be extended to the unlocking of the keyboard. The former definition will be used, but in cases where the output rate is very slow (e.g., 300 BAUD) and the time period from the first output character to keyboard unlock is significant, the modified definition may have to be employed. This decision should be based on observations of task performance factors at the terminal.

There are several related time measures in interactive computer use, and at least one is very important for understanding factors which affect user performance and satisfaction. This is the period called "user response time," "think time," or, by Sackman (65), "interarrival time." "Interarrival time is the interval between the completion of the last computer output and the insertion of the user's next input." Boies (8) defines user response time as "the time between the systems prompting the user to enter the next command (by unlocking the keyboard) and the user's depressing the carriage return." The combined user and system response times are frequently referred to as the "interactive cycle," "transaction cycle," or "command cycle." Figures 1 and 2 illustrate these definitions. For understanding the user's behavior in time, user response time is less than trivial.

4.4 User Response Time and System Response Time Dependencies: Method Chunks and Rhythms of Interaction

Several studies have revealed a positive correlation between user response time and system response time in actual interactive task performance (7,8). In their keystroke level model of task execution, Card, et al, find it necessary to precede task execution time with task acquisition time. "During acquisition the user builds a mental representation of the task, and during execution the user calls on the system facilities to accomplish the task." The length of the acquisition time period is a function of the larger task situation in which it occurs. This larger situation is, in turn, influenced by system response time in conjunction with human short term memory limits. Given a large task, such as editing a large document or record form, the user will break it into a series of smaller, manageable unit tasks. "The tasks and the interactive system influence the structure of these unit tasks, but unit tasks appear to owe their existence primarily to the memory limits on human cognition." The methods, or recipes, users follow in the step by step execution of unit tasks are composed of method chunks (see Simon, 69). The user organizes his work routines according to chunks whose size and frequency are largely a function of memory capacities. This requires a certain pace of system response (execution) time, whose length should not exceed that of the short term memory within which the next chunk resides. System response calibration efforts should also take into account that the user is more likely to pause between chunks than within chunks.

Precise and effective calibration can be attained only after repeated measurements of user performance of the unit tasks in real work situations. The most common chunk size and the most desirable user-system response rhythm must be obtained for specific classes of user task behavior at the terminal. Such classes or categories of behavior are data entry, line editing, record searching and verification, and record update. These may in turn be broken down into subunits such as keystrokes or the user's visual check for input accuracy after a reformatting of the record displayed.

Breaking down the classes into subtasks reveals the task required characteristics common to all kinds of user tasks in interactive computing. It will also provide the insight, gained during recomposition of these unit and subunit tasks, that there are different appropriate rhythms or tempos for different classes of user-interactive terminal activity. A major determinant of this tempo is, of course, system response time. The proper consideration of this parameter from a human factors orientation "views time as a variable which must be evaluated in correspondence with the operations being performed" (see Penniman and Perry, 58).

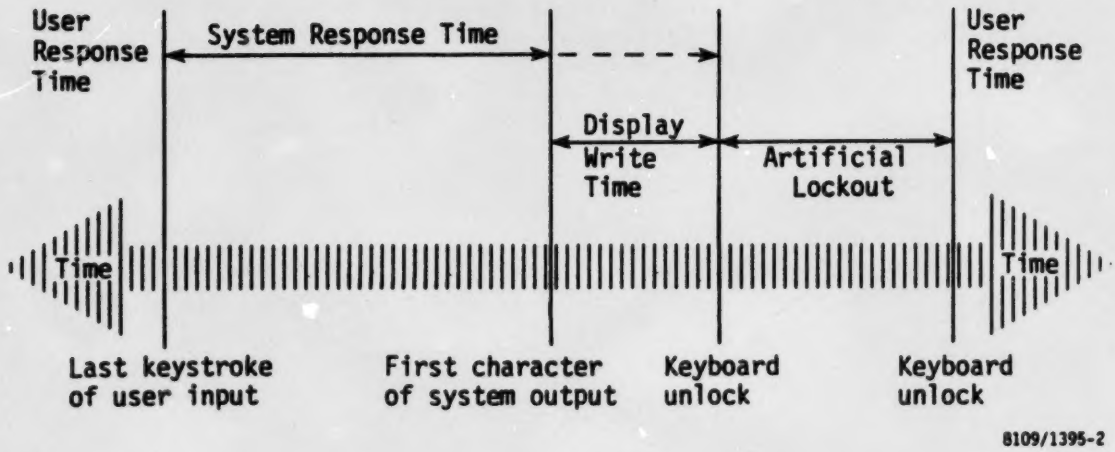
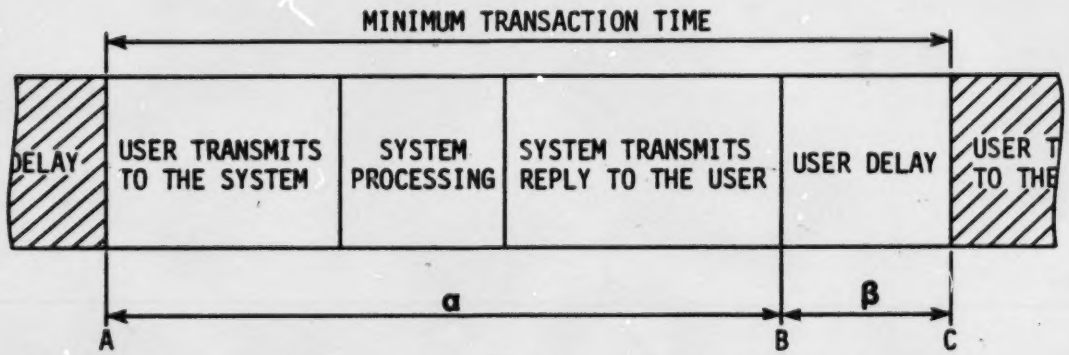


FIGURE 1. "Interarrival Time"



Each interactive cycle--the elapsed time from the beginning of one transmission to the beginning of the next--can be divided into two intervals. The more critical, α comprises the useful work (system processing) and transmission time. The other, β includes such things as think time.

8109/1395-1

FIGURE 2. "User Response Time"

(Kamerman, 34)

4.5 Two Fundamental Principles for Considerations of the User Interface in Interactive Systems

The psychological characteristics of human cognition and behavior present both opportunities and constraints for the interactive system designer. For example, in the development of "natural" command or query languages, human levels of discourse and cognition are generally viewed as challenging opportunities present at the leading-edge of research. On the other hand, time-relevant human characteristics seem to be viewed as constraints that must be accommodated, more or less, in the design of interactive systems. This simplistic attitude has prevailed: "We will provide as-fast-as-possible system response time, but there are these other system constraints..." This attitude clouds the understanding that user performance is to be maximized in any system tradeoff decision, and furthermore, that maximum user performance may not require the fastest possible system response time in all cases.

R.B. Miller, in his seminal study of "Response time in man-computer conversational transactions,"(49) offers two principles which have stood up well to the tests of experience and analysis over the past dozen years. The first is that a one-dimensional approach to the user interface (such as that embodied in the abstraction of "terminal man," or the view that all tasks performed by a terminal operator are not significantly different for the purposes of system hardware-software design) must be replaced by the realization that there are different classes of human action and purpose at terminals in interactive systems. Even more fundamental than this is the assumption that man is a system component who begs for an integrative understanding, and not just the delivery of the system's equipment and services. Miller's second principle derives from the first, namely that different human purposes and actions, manifest in the use of interactive terminals, will have different acceptable or useful response times. These principles and any attempted application of them need to be kept distinct, with the correctness of the latter tested in repeated simulations or through measurements of performance and attitudes in real-life working situations.

4.6 Psychological Factors and Response Time Requirements

Considerations and empirical findings supporting these principles have been published by many researchers and designers (6,8,9,20,23,25,40,42,66), and the orientation is primarily psychological. Additional considerations pertinent to the response time issues have emerged from observations of user behavior in actual problem-solving and task-performance environments. Psychological needs may be translated into system response time requirements. R.B. Miller's definition of "need" is worthy of attention: "A need or requirement is some demonstrably better alternative in a set of competing known alternatives that enable a human purpose or action to be implemented." We might only add "...to be implemented most effectively." In conversationally paced interaction, the user exhibits an expectancy threshold. Some response is expected short of this threshold to maintain continuity of thought. Disruptions in this expected continuity force other thought processes to occur and may slow the effective pace or rhythm of the interaction. Evidence seems to indicate that the threshold is 2 to 4 seconds when continuity of thought is required for ongoing processing activity (9,42,49).

Van Cott and Warrick (78), in their study of humans as information storing and processing systems, distinguish, as do many psychologists, between short-term and long-term memory. Short-term memory is "receiving transitory inputs from an operating system, temporarily storing the information, and almost immediately recalling it to control equipment or to make operational decisions." Sensory-input maintenance and recall are functions of experience and training, but as the time between the presentation of data and its recall is decreased, the probability of correct recall increases. The limits of short-term memory explain why humans clump information into chunks. But chunks to be retained beyond the moment must be transferred to long-term memory. Retrieving needed information from long-term memory is not only more time-consuming, as Shneiderman has pointed out (67), but doing so can inhibit interactive problem solving: "Users must constantly rehearse their knowledge to maintain the information."

Clumping activity occurs spontaneously in human activity to satisfy short-term memory, and also to mark a point of completion or "closure." The human need for relief of cognitive effort at some closure point can partly be explained by the efforts involved with short-term memory. Anxiety at not being able to "let go" of crucial data also explains the need to reach a closure point. There is always the felt danger of losing the contents of short-term memory due to noise and other distractions. R.B. Miller derives an obvious guideline from these considerations: "The rule is that more extended delays may be made in a conversation or transaction after a closure than in the process of the closure."(49) Closure is the completion of some task leading to a sense of relief.

Tasks must be organized to account for this need, including the determination of relative lengths of system response time. A violation of this principle is illustrated by a terminal responding faster to the update and send of an entire record than it responds to the editing update of a single line, or to a request for a reformatted display to be checked prior to the final update and send.

Martin suggests that terminal tasks requiring continuity of thought and the retention of key operational information in short-term memory should have a system response of no more than two or three seconds. " A ten-second response when doing something elaborate with a terminal is insufferably frustrating."(42) And Miller suggests this rule of thumb: "Response delays of more than two seconds should follow only a condition of task closure as perceived by the human."

Certainly closure needs and short-term memory capacities vary among humans in different environments, but the principles seem to be sound enough to warrant measurements to establish the optimal response times for given kinds of activity. The stakes in maintaining desired levels of human efficiency and productivity are high because, as Miller points out, "There is not a straight-line decrease in efficiency as the response delay increases; rather, sudden drops in mental efficiency occur when delays exceed a given point."

Specifying these efficiency "step-down" points in system design will have a far greater impact on user performance and acceptance than attempting to reduce an aggregate measure of system response time by a second or two. Such

specifications are not unrealistic and they may include a range within which the nominal value may fluctuate. Response time specifications should include tolerance values. The acceptable tolerance range of delay for a given category of response time is that range not noticeable to the user under actual working conditions. Evidence suggests that this is usually between 2.0 and 3.5 seconds, but that it may vary under some conditions.

Many studies have confirmed the effects of long system response times on longer user response times, degraded user performance, and increased user dissatisfaction with the system, often resulting in decreased use or total rejection (3,8,9,26,29,33,38,44,65,74,78). The studies which indicate that delayed (more than ten seconds) system responses either do not decrease productivity or, in certain problem-solving activities, actually contribute to better performance, are few and apply to very special cases of complex problem-solving situations. In several studies where artificial "lockout" was applied, user frustration and dissatisfaction increased significantly (7,29,79). As Sackman (65), and Boehm, et al.(7) discover, the beneficial effect of prolonged system response time on performance seems limited to activities requiring creative or highly complex problem-solving activities. The more generally applicable conclusion has already been reached: not all response times need be equally short in duration.

The creative terminal user, programmer, and scientist usually have the freedom to leave the terminal at their own discretion. This luxury does not usually apply in a production environment or at a busy service counter. Simon, referring to the human propensity for "job swapping" (turning to another task in the meantime), suggested that responses that were not immediate should be artificially delayed to allow the user to job swap (70). He suggested that a minimum of several minutes would be necessary. The conclusion however, is that delays that are long enough to disrupt the primary task, but are too short to allow swapping to another one, are delays that should be designed out of the system (see Nickerson, et al., 52).

4.7 The Effects of Variability in Expected Response Times

Simon's suggestion of job swapping was offered as a partial solution to the problem of unpredictable, extended delays of system response. With advances in hardware and storage methods for large data base systems, recent evidence has shown that decreases in user performance, as well as increased frustration expressed by users, results from the variability of response times within a common class of terminal activities (45,44,51). Nickerson was one of the first to discover that the variability of the response time distribution may be as much of a concern to the user as the mean response time (51). The degree to which a user is frustrated by a delay is not a simple function of its duration. "Rather it depends on such psychological factors as the degree of uncertainty in the mind of the user concerning how long the delay will be, the extent to which the actual delay contradicts his expectations, and what he considers to be the cause of the delay."

Shneiderman suggests that users may prefer a system which always responds to a certain command or inquiry in 4.0 seconds to one which varies from 1.0 to 6.0 seconds, even though the average in the second case might be less than 4.0 seconds. In addition to removing the psychological bases of frustration caused by inconsistent response times, users can pace their activities more productively if the response time is expected and uniform. User think time will be improved if attention can be released from the terminal screen in predictable patterns. Given task-performance and short-term memory requirements, the attempt to arbitrarily minimize variance should remain within the tolerance values dictated by these fundamental user requirements.

Martin suggests that the standard deviation of response times for one transaction type should not exceed half the mean response time (42). Extremes in response time should be designed out of the system. If most response times are under five seconds, there may be no need to make an attempt to "even-out" highly variable responses. For extremely long response times (more than 15 seconds), the user input should be acknowledged in some manner by the system, and Shneiderman even recommends that the system inform the user of how long the delay will be. When the length of the delay cannot be ascertained, it may be better to block out a period of non response sufficient to correct the problem, than to successively display "Retry Momentarily" (whose moment?) or "Retry in 15 Minutes." Terminal operators have been known to return to the terminal many times in succession, just to receive a new display, "Retry in 15 Minutes."

4.8 Appropriate Statistical Measures for System Response Time

Average response time, as a statistical measure, has inherent limitations. In the analysis of quantitative data, the appropriate statistical measures depend on the nature of the underlying distribution. The average can be misleading because it hides a lot of information. When the distribution is not normal and the range is very large, the average provides no meaningful data to the user who is more concerned with the extremes and variability of response time. A possible explanation for the fact that users frequently estimate average response time higher than it actually is, may be what has been called the "fallout" or "backlash" effect on the user of extremely slow or highly variable response times. The high impact of the extremes may suggest that it

is more important to reduce the extremes than the average. Realistic measures of response time for management information reports must include the distribution and the standard deviation. If the standard deviation is near to or greater than the mean, a problem exists which the user has already noticed.

4.9 Criteria for Determining the Optimal Mix of Response Times Summarized

Optimal system response time, as defined in Section 3.2, dissolves under analysis to a question of what is the set of optimal response times for this or that kind of functional behavior performed at the user interface in an interactive system. It has been suggested by Shneiderman (67), that acceptable response time is a function of the command type, by Engel and Granda(22), that it is a function of the perceived complexity of the request and of required system activity. Both of these are true as far as they go, but additional considerations must be brought to bear in determining the optimal mix of response times in particular functional applications of interactive systems. These range from bibliographic retrieval to the updating of fund or circulation transaction records.

The psychological requirements discussed above must be honored by a commitment to apply behavioral techniques of observation and measurement to actual user populations so that data can be derived leading to response time requirements. These requirements then must be specified in the design stage of system development. Capturing a sense of the requirements of the workplace is equally important. This includes the user's perception of his role, his sense of good service, or his awareness of production quotas or other performance measures applied by management.

Human responses to poor system response can range from genuine frustration, to unwillingness to use the terminal, to using poor system performance as an excuse to slack-off. Task-restructuring by the user is often a forced inevitability in the face of slow or inconsistent response time. But as Engel and Granda have reminded us, in many functional activities, task rearrangement is impossible because interactions to the system are lock-stepped. "Therefore, time intervals between input and response output tend to be dead time for the user."(22)

The matter is not a simple one, to be sure. A simple formula for the one acceptable, universally applicable system response time for all interactive activities does not exist. Even before all the system-side capacities and constraints (a function of architecture, terminals, telecommunications processors, queuing algorithms, file organization, and data base management software, etc.) are brought into the decision and design arena, all of the relevant determinants from the user's side must be examined and weighed carefully for development into functional requirements. These requirements should be defined early in the iterative process of the design and development of new products, or in the enhancement of existing ones.

5. RESPONSE TIME MEASUREMENT AND SPECIFICATION IN THE SYSTEM DESIGN PROCESS

5.1 User-Relevant Measurements of System Response Time

It is outside the purposes of this report to recommend specific methodologies and techniques for the measurement of system response time. But an attempt has been made to identify and clarify the pertinent locus and components of system response time from the user's point of view and interest. The response time perceived at the terminal for various classes of transactions must be measured to provide data for user questionnaires and interviews. One purpose of these interviews is to discover user preferences for response times appropriate to various rhythms of terminal work activity. The measurement of system response time will tell us what it is under various conditions at a specific terminal, but it will not reveal what it ought to be for specified classes of transactions in different task-performance environments.

As we have seen, determining optimal system response time is a multi-valued decision problem, which nevertheless needs to be resolved prior to the development of the functional specifications for any system design. User surveys, in-depth interviews, and unobtrusive observation of user sessions are some of the methods by which the subjective utility value placed on various response times by the user can be ascertained. The mere mechanical measurement of the arrival and departure of electrons at the terminal will not provide much valuable data for design purposes, but can and should be used to confirm that decisions have been implemented, and to convey terminal-specific performance information to the user. The work done by Abrams, Cotton, and others at the National Bureau of Standards (1,2,3,30) with the Network Measurement System is a sound user-oriented approach, as is the work of Carlson and Ferreira (11,12).

5.2 A Rating Scale for System Response Time Requirements Specification

For the formal process of specifying user requirements, a system response time rating scale is proposed. The parameters are identifiable, measurable, and are intended to be a common, descriptive reference point throughout the design--implementation--evaluation process.

SYSTEM RESPONSE TIME SPECIFICATION SCALE

RATING	TIME (secs.)
Rapid	0 - 0.999
Fast	1 - 2.999
Moderate	3 - 4.999
Slow	5 - 9.999

The motivation behind this scale is to separate normative, prescriptive discourse about response time from the descriptive categories required for functional specifications. "Good," "poor," "unacceptable," and "intolerable" are terms that can be used only in relative value judgements. "Rapid" response time may be no more optimal than "fast" response time. "Moderate"

response time may be poor for one class of transactions or type of terminal display (reformatted screen or display of a workform), but quite good for complex searches of the data base. Studies have shown that users are sympathetic to the need for such gradations in response time, and they may find this a convenient way to express their choices for the desired response time periods for different kinds of interactive task execution.

5.3 The Place of Response Time Specification in the Design Process

High-level theoretical expositions of the design process for real time, interactive systems now share the principle that response time requirements must be identified prior to undertaking system design (42,67,77). These requirements, arrived at by analysis of each transaction as seen from the user's point of view, should apply to each kind of transaction and should be specifically embedded in the specifications as design objectives. Tebbs and Collins (77) warn that "it should not be unnecessarily frozen in the systems specification." The inclusion of a tolerance range is acceptable for most transactions, due to the human propensity to recognize the presentness of a perceived event for about two seconds. In recommending different response times for different terminal operations, Martin teaches that "the systems analyst must review all the functions that his system will perform and write down the desired response time for each."(42)

Shneiderman's recent survey (67) of the design process for interactive systems synthesizes the best insights and recommendations of today's major designers or design teams. This process is outlined in Table 2. Response time considerations play a role in task analysis at the "semantic" level, because task sequences should be grouped into transaction units that satisfy user desire for closure. At the level of "syntactic" design, "response time requirements for each command type should be listed with means, minimums, and maximums." This specification of response time requirements should precede software development, and testing should include measurements of potential response time degradation under heavy and anticipated peak loads. Finally, ongoing evaluation of the system must include monitoring of time-related performance measures. The design should permit modifications to the existing response time mix when required by changing needs of the users, or internal system contingencies.

TABLE 2. Design Process for Interactive Systems
(Shneiderman,67)

1. Collect information.
   - -organize design team
   - -obtain management participation
   - -submit written questionnaires to users at all levels
   - -conduct live interviews where possible
   - -read practical and academic literature
   - -speak with users and designers of similar systems
   - -estimate costs and cost/benefit
   - -prepare schedule with observable milestones

2. Design semantic structures.
   - -define goals and establish a hierarchy of requirements
   - -consider task flow sequence alternatives
   - -organize operations into transaction units
   - -create application domain data structures
   - -develop application domain operators
   - -specify privacy, security, and integrity constraints
   - -obtain agreement on semantic design

3. Design syntactic structures.
   - -compare alternative display formats
   - -create syntax for operators
   - -prepare system response formats
   - -develop error diagnostics
   - -specify response time requirements
   - -plan user aids and help facilities
   - -evaluate design specifications and revise where necessary
   - -carry out paper and pencil experimental test

4. Specify physical devices.
   - -choose hard or soft copy device
   - -specify keyboard layout
   - -select audio, graphics, or peripheral devices
   - -establish requirements for communications lines
   - -consider work environment (noise, lighting, etc.)

5. Develop software.
   - -produce top-down modular design
   - -consider modifiability, generality and portability
   - -emphasize reliability and maintainability
   - -provide extensive system documentation
   - -conduct thorough test

6. Devise implementation plan.
   - -assure user involvement at every stage
   - -write and field test training manuals
   - -implement a training subsystem or simulator
   - -provide adequate training and consultation
   - -apply spiral/layered/phased approach to implementation
   - -aim to please the users

7. Nurture the user community.
   - -provide on-site telephone or consultants
   - -offer online consultant
   - -develop online "gripe" command or suggestion box
   - -make user news available online
   - -publish newsletter for users
   - -organize user group meetings for discussion
   - -respond to user suggestions for improvements

8. Prepare evolutionary plan.
   - -design for easy refinement or repair
   - -measure user performance regularly
   - -improve error handling
   - -carry out experiments
   - -sample feedback from users by questionnaires and interviews

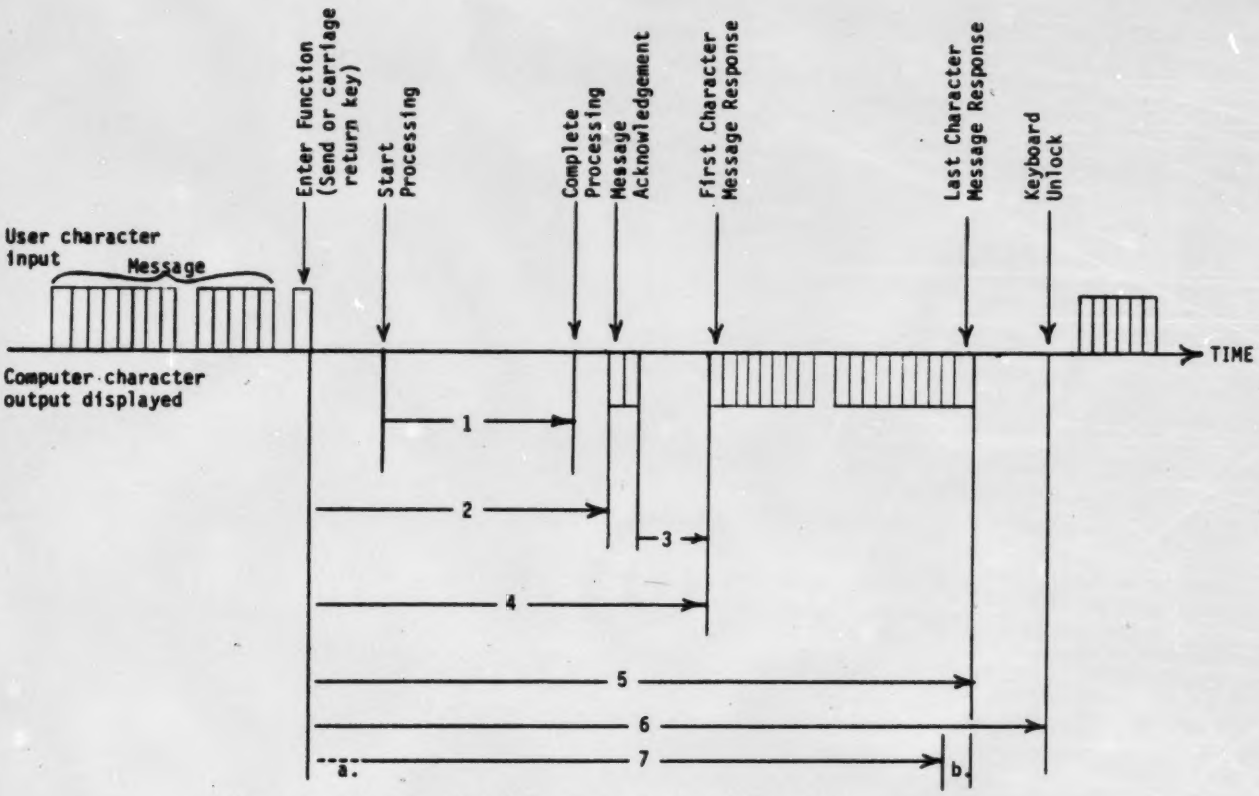
The insights of R.B. Miller are once again worthy of our consideration:

> The need for efficient systems planning and development will require that design and evaluation be reciprocal activities working in tandem. That is, a design hypothesis should be evaluated in order to improve the design which, when modified is again evaluated. A major tyrant will be development schedules and costs. Clearly, evaluation should consist of a descriptive structure and notation, and of sampling and measurement characterizations which are diagnostic with respect to design optimizations, the making of design tradeoffs and design decisions. This requires that the evaluation procedures enable diagnostic assessment within gross quantifications. As a gratuitous comment, it is by no means apparent that the genuinely useful function of evaluation is clear to many specialists in the evaluative arts and crafts. A useful function is not merely to reach a decision to accept or reject a design or system -- a decision which, by the way, must generally go far beyond any measurement of tangibles. A useful function of evaluation is that of pointing towards what modifications would make what kind of improvement and how much. It should be a heuristic art, rather than merely a meter reading craft.(48)

The end user, directly or indirectly, is playing an increasing role in shaping the demand side of the information marketplace. Success in the information services and facilities sector of the marketplace, over the long run, will depend more and more on the involvement of the user in the design process, especially as that design impacts on the user interface. Good design must be based on clearly specified user requirements, and user requirements specification must be derived from knowledge gained through observation of, and communication with, the end user. Only then will the ingenuity and skill of the system builders be enhanced by the findings of practitioners of the "heuristic art" of evaluation.

6. APPENDIXES

APPENDIX A. Various Measures of System Response (Adapted from Abrams and Cotton,2)



1. Inquiry Response Time (Silverman and Yue, IBM, 1973)
2. Response Time, System Responsiveness (Kamerman, IBM, 1969)
   Stimulus-Acknowledgement Delay (Abrams and Cotton, NBS*, 1975)
3. Acknowledgement-Response Delay (Abrams and Cotton, NBS, 1975)
4. Stimulus-Response Delay (Abrams and Cotton, NBS, 1975)
5. Turnaround Time, Response Time (Boehm, et al., RAND, 1971)
6. System Response Time (Boies, IBM, 1974)
7. System Response Time (OCLC Technical Bulletin 88, 1980)
   a. 1/2 time delay between system polls of a terminal
   b. the moment last character departs the Communications Processor (excludes line delays and terminal display delay)

* NBS = National Bureau of Standards, U.S. Department of Commerce

APPENDIX B. Guide to the Scope and Purposes of User Interface Studies Reviewed*

Nature of the Study	Studies (numbers correspond to those of the bibliography)
A. Report or analysis of empirical research**	3,7,8,10,14,17,19,20,21,26,29,32,40,44,45, 50,56,58,65,74,76,80,82
B. Analysis of research methods and models	3,4,5,9,10,13,15,16,17,24,25,27,28,30,32, 34,36,37,38,39,41,46,47,49,51,55,58,59,64, 65,66,67,68,69,70,75,76,78
C. Time parameter measurement techniques	1,2,3,4,8,10,11,12,13,17,30,32,34,36,37, 54,55,58,68,75
D. Integrative, usually prescriptive, state of the art reviews	2,6,9,16,18,20,22,23,26,27,31,33,38,41,42, 43,48,49,50,51,52,53,57,61,63,64,67,72,73, 77,78,79,81
E. Annotated bibliographies, bibliographic essays, and literature reviews***	6,38,43,46,53,59,61,62,67,79

* Some studies are multi-purpose in nature, and are so indicated in this table.

** Includes studies and data analysis based on controlled experiments, surveys or interviews, and extensive experience and interaction with system users.

*** The EDP Performance Review devotes its March issue each year to an annotated bibliography of the previous year's performance related literature. Subject and author indexes are provided with these annual issues.

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Boehm, Seven, and Watson (1971); 21, 27, 28
Boies (1974); 5, 27, 28
Carbonell, Elkind, and Nickerson (1968); 1, 18, 20, 27
Card, Moran, and Newell (1980); 8, 15, 28
Carlson (1976); 8, 23, 28
Carlson and Ferreira (1977); 23, 28
Chang (1975); 12, 13, 28
Church and Tidball (1980); 24, 28
Deese (1979); 8, 28
Eason (1976); 10, 11, 28
Engel and Granda (1975); 5, 22, 28
Fitter and Sime (1980); 18, 28
Gagne (1962); 18, 28
Gaines and Facey (1975); 20, 28
Grochow (1972); 8, 28
Grossberg, Wiesen, and Yntema (1976); 21, 30
James (1980); 20, 28
Kamerman (1969); 17, 27, 28
Lancaster and Fayen (1973); 20, 28
Martin, J. (1973); 3, 18, 19, 21, 24, 28
Martin, T. (1973); 24, 28
Melnyk (1972); 20, 21, 28
Miller, L. (1977); 21, 28
Miller and Thomas (1977); 3, 8, 28
Miller, R. (1971); vi, 3, 9, 26, 28
Miller, R. (1968); 3, 18, 19, 28
Nickerson (1969); 1, 2, 3, 21, 28
Nickerson, Elkind, and Carbonell (1968); 1, 20, 28
Normore (1980); 4, 28
Pearson and Bailey (1979); 8, 28
Penniman and Perry (1975); 16, 28
Pew, Baron, Feehrer, and Miller (1977); 2, 28
Ramsey and Atwood (1979); 2, 28
Sackman (1970); 2, 15, 20, 28
Shneiderman (1979); 3, 18, 21, 28
Shneiderman (1980); 3, 19, 22, 24, 25, 28
Silverman and Yue (1973); 12, 27, 28
Simon (1974); 15, 28
Simon (1966); 20, 28
Stevens (1979); 5, 6, 28
Streeter (1972); 20, 28
Svobodova (1976); 7, 28
Tagliacozzo (1977); 8, 28
Tebbs and Collins (1977); 24, 28
Van Cott and Warrick (1972); 19, 28
Walker (1971); 20, 28